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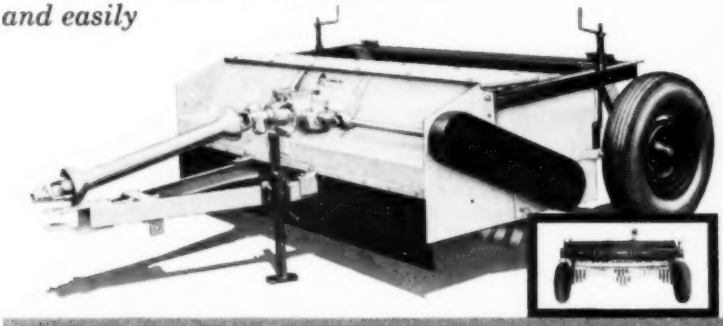

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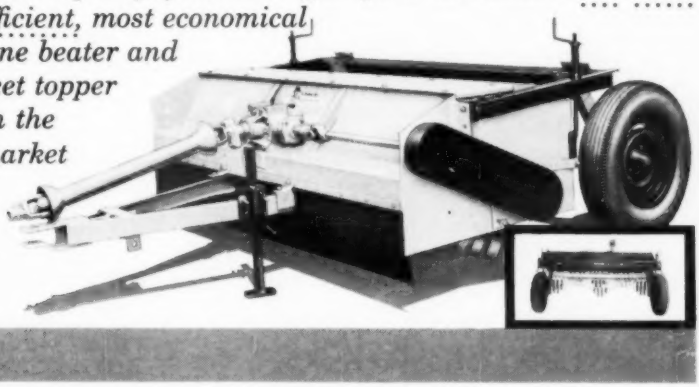

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BLACK SPOT OF POTATOES[1]

R. L. Sawyer and G. H. Collin[2]

Black spot of potatoes has been recognized as a major potato defect in parts of Europe for over 50 years. In the United States it was first reported on Long Island in the 1930's, but was not important in most potato areas until recently. Since 1950 most of the major potato areas of the United States have considered black spot in research programs.

Black spot as discussed in this paper is a sub-surface discoloration caused by a mechanical bruise in handling. It occurs most frequently at the stem end of tubers about one-quarter of an inch below the skin. The skin of the tuber need not be damaged to the extent of a cut or break for the disorder to occur. The color of the black spot can vary in intensity from a light grey or bluish grey to an intense black color. The discoloration is observed in susceptible potatoes 24 hours after bruising. Only information pertaining to the scope of this paper has been reported. For a complete review of black spot research Scudder (12), and Jacob (7) are recommended.

Workers (1,3,6 and 12) have come to the conclusion that black spot is not an infectious disease. They agree that tubers, susceptible to black spot, caused by a combination of field factors, develop discoloration only after bruising by mechanical injury.

Of the various essential elements potassium has had the greatest influence on black spot. van der Waal (13), Verhoeven (14) and others in Europe as well as Scudder (12), Jacob (7), and Oswald (10), in the United States recognized the influence of potassium on black spot. Although commercial control of black spot by high potash fertilization has been obtained in Europe, workers in the United States have been in agreement that the reduction is not sufficient to be of commercial value. deBruyn (3), Massey (8), and Scudder (12) found a positive correlation between black spot and specific gravity. Massey (8) indicated that the effect of potash on black spot was indirect with potash influencing specific gravity and thus influencing black spot.

The incidence of black spot increases with storage time. Dutch workers (1 and 3) observed that factors which tended to lower water content of tubers resulted in increased specific gravity and greater susceptibility to black spot. de Bruyn (3) pointed out the increase in black spot as specific gravity increases during storage. Boyd (2) concluded that turgor pressure was associated with black spot susceptibility but could not relate this to an explanation of varietal resistance. Wiant (15) observed that the soft, depressed, pressure bruise areas of tubers were most susceptible to black spot. Collin (4) indicated that tuber firmness may determine both varietal susceptibility and the specific gravity relationship.

Black spot index as discussed in this paper takes into consideration the percentage of tubers showing black spot and the average severity of the black spot in a given lot. The severity rating is 0 to 9 with 0 indicat-

[1]Accepted for publication October 21, 1959.
Paper No. 427, Department of Vegetable Crops, Cornell University, Ithaca, N. Y., Long Island Vegetable Research Farm, Cornell University, Riverhead, N. Y.

[2]Associate Professor of Vegetable Crops and Graduate Assistant, respectively.

ing no black spot and 9 very severe black spot. The index was derived from the formula

$$\frac{\text{Per cent black spot} \times \text{severity reading}}{10}$$

CELL TURGOR

It has been suggested (3) that the potato cell develops color, when upon bruising the cell is killed or injured, but the enzyme, tyrosinase, and its substrates remain active. The response to injury of the cell has been related to both turgor and physiological age.

Material and Methods

To determine the effect of turgor, tissue discs were cut from the vascular regions of tubers and exposed to a concentration range of mannitol solutions. The discs were bathed in the various solutions for one-half hour and bruised by a 20 gram weight dropped 10 centimeters through a vertical cylinder.

Results

Regardless of variety or age of tubers sampled, only discs which had been exposed to a concentration of 0.8M or greater developed color after bruising, whereas discs bathed in more dilute solutions did not develop color after bruising. Discs from long stored and extremely susceptible Katahdin tubers were completely resistant to color development after bathing in distilled water. In comparison, the discs of freshly harvested, non-susceptible variety tubers developed extreme color upon bruising after bathing in 0.8M mannitol.

That susceptibility to bruising induced by bathing in plasmolysing solution was due to reduction of turgor and not to leaching of some enzyme or substrate was proven by illustrating the complete reversibility of susceptibility. A large number of discs were first bathed in 0.8M mannitol solution, then distilled water and finally returned to 0.8M mannitol solution. After bathing in each solution, discs were sampled, bruised, and observed for coloration to measure susceptibility. Susceptibility is completly reversible, illustrated by Table 1, and is therefore primarily determined by tissue turgor.

TUBER FIRMNESS

Black spot has been associated with pressure bruises of potatoes in storage for many years. The softer the tubers become, the more susceptible they are to pressure bruises. This phase of the investigation was set up to determine how closely black spot and tuber firmness were associated.

Material and Methods

In order to measure fine degrees of tuber firmness something more accurate than thumb pressure was necessary. A measurement was desired which could be used to determine yearly variation. A durometer used to measure hardness of rubber was adapted to measure firmness of potatoes.

TABLE 1.—*The darkening of discs of stored Pontiac tubers after bathing in various mannitol sulutions.*

Bathing Treatment	Not Bruised	Bruised
Not bathed	No color	No color
Bathed in 0.8M mannitol	No color	Extreme darkening
Bathed in 0.8M mannitol followed by distilled water	No color	No color
Bathed in 0.8M mannitol, distilled water and finally 0.8M mannitol	No color	Extreme darkening

A ball tip of stainless steel with an outside diameter of .1800 of an inch protruded through an end plate. Potatoes were pressed against the ball tip until they touched the end plate. A dial reading 1 through 100 indicated how far the ball tip dents the surface of the tuber without breaking the skin in any way. A reading of 100 indicated no denting of the surface and

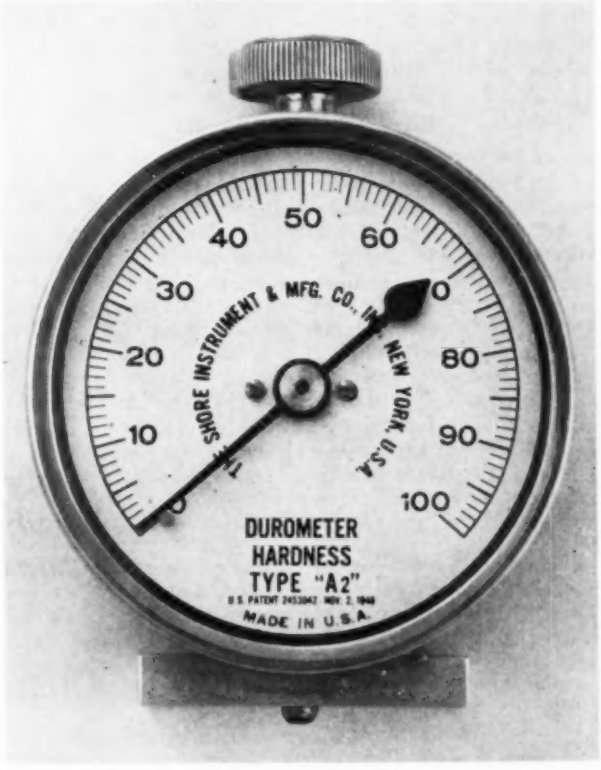

FIGURE 1.—Hardness meter converted to measure tuber firmness.

very firm tubers. A reading of 0 indicated very soft tubers. The durometer used to measure tuber hardness is shown in Fig. 1.

The durometer was used in 1954, 1955, 1956 and 1957 on potatoes from experimental and grower storages. In some cases both a hardness and a black spot determination were made on individual tubers. For large experimental samples a hardness reading was made on 30 tubers and black spot determination on a 20-pound sample.

Results

The firmness of tubers and black spot have a very close association. Table 2 indicates this association. Firm tubers had the least black spot, with the soft tubers showing the most.

As tuber firmness fell below a certain point, the incidence of black spot increased rapidly. The association of black spot and tuber firmness is also indicated in the data presented in Tables 5 and 6.

VENTILATING AIR

If tuber firmness is an essential physical factor in the black spot reaction, the amount of air used for ventilating storages and the moisture content of the air should influence black spot.

Material and Methods

Samples of potatoes for black spot analysis were taken from large experimental bins which were being used to study the effect of rate of air and moisture content of air on storage quality of potatoes. Each room was 400 bushel capacity equipped with forced air ventilating systems of the proportioning type. In order to obtain additional information each room was subdivided into 4 sections containing 100 bushels of potatoes, each section of different cultural background. Incoming air entered the pile through a duct under the center of each room. When tubers were removed from storage, each subdivision within a room was sampled for black spot at the top, center and bottom.

In 1955, 1956 and 1957 rooms were included in the study which received ½ and 1 cubic foot of air per minute per bushel of tubers. In 1956, 1957 and 1958 rooms were included in the study with moisture added to the ventilating air and with no moisture added to the ventilating air.

Results

Black spot was consistently worse in the rooms with 1 cfm than with ½ cfm. These results are given in Table 3 and each figure is an average of all black spot samples taken for the air rate given. The differences in black spot due to air rate were statistically significant each year.

Moisture applied to the ventilating air decreased the incidence of black spot. These results are given in Table 4. One-half cfm per bushel of tubers was used in all comparisons given.

Table 5 includes both air rate and moisture application results for 1957, and indicates how hardness of the tuber, shrinkage and black spot are associated. The room with ½ cfm and no moisture had the softest

TABLE 2.—*Effect of tuber firmness on black spot with Katahdin tubers.*

Hardness Index	Black Spot Index
80.8	2.3
79.6	5.4
78.6	5.6
75.9	6.4
75.5	8.4
74.1	22.5
Correlation Coefficient	.7876

TABLE 3.—*Effect of ventilating air on black spot.*

Amount of Ventilating Air	1955	1956	1957
1 cfm per bushel	11.5	12.1	17.5
½ cfm per bushel	6.3	8.9	12.6

TABLE 4.—*Effect of moisture application to the ventilating air on black spot.*

Moisture Application	1956	1957	1958
With moisture	8.3	12.6	9.0
Without moisture	18.0	32.9	32.2

TABLE 5.—*Effect of air rate and moisture application on hardness, shrinkage and black spot of Katahdin tubers stored 5 months.*

Treatemnt	Hardness Index*	Per cent Shrinkage	Black Spot Index
½ cfm—no moisture	80.9	6.7	32.9
1 cfm plus moisture	82.2	6.2	17.5
½ cfm plus moisture	83.0	5.0	12.6

*Hardness index runs 1 through 100 with 1 soft and 100 hard.

TABLE 6.—*Tuber firmness, weight loss, specific gravity, and black spot of three varieties of potatoes stored for three months.*

Variety	Firmness Index	Per cent Weight Loss	Specific Gravity	Black Spot Index
Ontario	68.9	8.11	1.0661	30.7
Katahdin	74.2	3.80	1.0765	22.5
Pontiac	76.7	4.73	1.0593	6.0

tubers, the most shrinkage and the highest incidence of black spot. Adding moisture to a ventilation rate of ½ or 1 cfm gave a reduction in black spot, shrinkage and also resulted in firmer tubers than ½ cfm with no moisture. Moisture added to ventilated rooms at ½ cfm gave firmer tubers, less black spot and less shrinkage than moisture added to ventilated rooms at 1 cfm.

SPECIFIC GRAVITY

Taking the specific gravity of tuber samples has been a part of the black spot determination procedure for the past 15 years. There has been a consistent correlation between specific gravity and black spot with a given variety. The work reported here on specific gravity was aimed at determining if the black spot specific gravity association could be related to tuber firmness.

Materials and Methods

For the data shown in Fig. 2, tubers of Katahdin variety, grown at the Research Farm, all of the same cultural and storage background, were separated into specific gravity groups after 4 months storage at 40° F. The firmness of the tubers and black spot was determined from each specific gravity lot .

Three varieties covering the range of susceptibility to black spot were included in the work presented in Table 6. The varieties were grown at the Research Farm and all were subjected to the same cultural and storage environment. Each variety sample consisted of 20 tubers identified by numbers. Weight loss, specific gravity, firmness and black spot were determined for each tuber.

Results and Discussion

The specific gravity of tubers appeared to be related to tuber firmness as indicated in Fig. 2. The black spot incidence increased rapidly above the specific gravity of 1.075. Surface injuries seemed characteristic of tubers falling into the higher specific gravity groups.

The data presented in Table 6 indicated that tuber firmness may determine varietal susceptibility. There was no relationship between specific gravity and firmness when all varieties were combined, and no relationship between varietal black spot susceptibility and varietal specific gravity. This indicates, as have variety trial results, consistently, that the relationship between specific gravity and black spot holds true only within a given variety and does not explain varietal susceptibility.

Varietal Susceptibility and Lenticel Structure

Assuming that the main source of water loss from the potato is through lenticels, the lenticel structure, and skin character, of varieties susceptible and non-susceptible to black spot were investigated.

Materials and Methods

Tuber materials were obtained from the 1956 variety trials of the Long Island Vegetable Research Farm to insure uniform soil and cultural

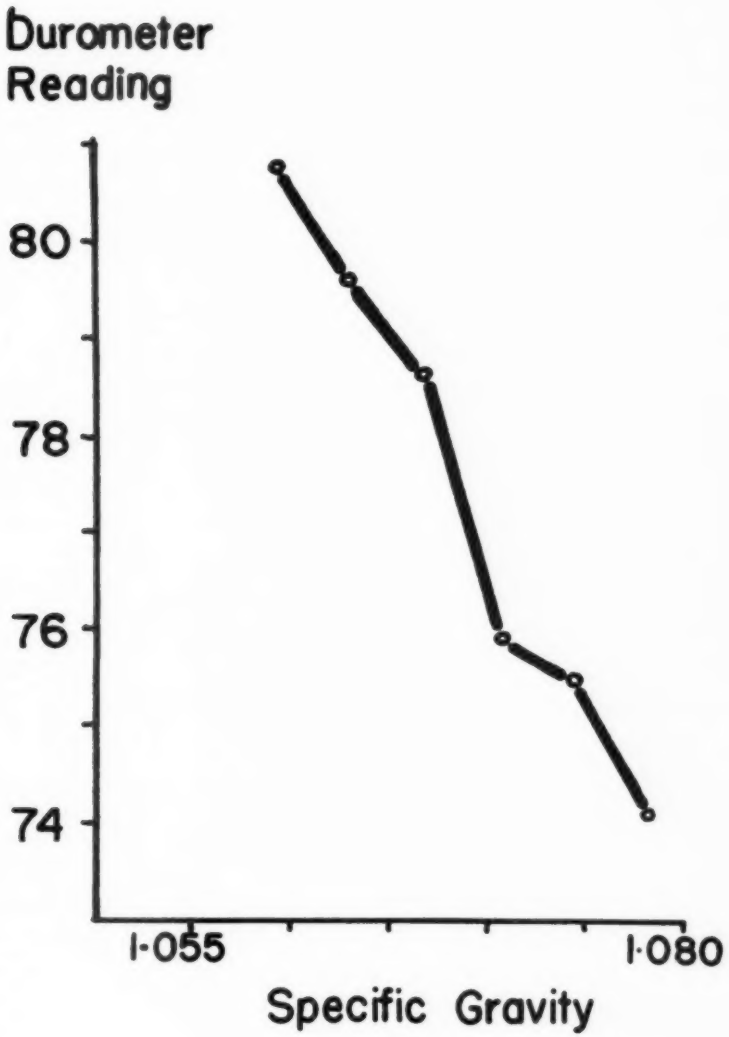

FIGURE 2.—Relationship of specific gravity and tuber firmness measured with a firmness meter.

conditions. One-half centimeter blocks of tissue were selected from stem end portions of tubers. Sections 30 microns in thickness were immediately cut using a CO_2 freezing microtome. The sections were stained for 30 minutes in Gentian Violet. From the slides, the lenticel structure of each variety was characterized selecting lenticels which appeared to be of normal size for the variety. Such characterization was difficult because of the amount of variability. Data were also obtained on character, thickness and number of cells in the phellum.

Results and Discussion

Pontiac lenticels had a mass of suberized cells approximately 700 microns in peripheral length and 30 microns deep. The lenticel opening from the tuber surface varied from 30 to 60 microns in diameter. The lenticels of Green Mountain, Katahdin and Ontario were characterized by a mass suberized tissue 1,500 to 2,000 microns in peripheral length and 500 to 700 microns deep. The lenticel opening was approximately 200 microns in diameter. Immediately beneath the lenticular opening was a loose mass of large parenchyma cells about 200 microns in diameter. In the tubers of the Ontario and Green Mountain varieties there was a suggestion of cell disintegration and in extreme cases vacuoles occurred beneath the lenticel. Figure 3 is a diagrammatic drawing which typifies a Pontiac lenticel. Figure 4 is a diagrammatic drawing which typifies a lenticel of Green Mountain, Katahdin and Ontario varieties.

The phellum of Pontiac variety had the greatest number of cells in depth and Ontario variety had the least. Ontario phellem was composed of a relatively few large cells whereas Pontiac phellem was shallow, with small cells, and with the retention of a compressed layer at the periphery. The results on phellem depth are indicated in Table 7.

Taking into consideration the structure of phellem and lenticels, loss of moisture should be least from the Pontiac variety, greatest with the

Table 7.—*Depth of phellem layer and lenticel number in Green Mountain, Katahdin, Ontario and Pontiac varieties.*

Variety	Mean	Phellum Depth Standard Deviation
Green Mountain	7.2	1.3
Katahdin	7.2	1.6
Ontario	4.5	1.0
Pontiac	11.0	1.8

Table 8.—*Association between shrinkage and black spot among varieties.*

	Black Spot Index		
	Trial 1	Trial 2	Trial 3
Low shrinkage varieties	21.3	46.4	18.6
High shrinkage varieties	42.1	60.0	33.0

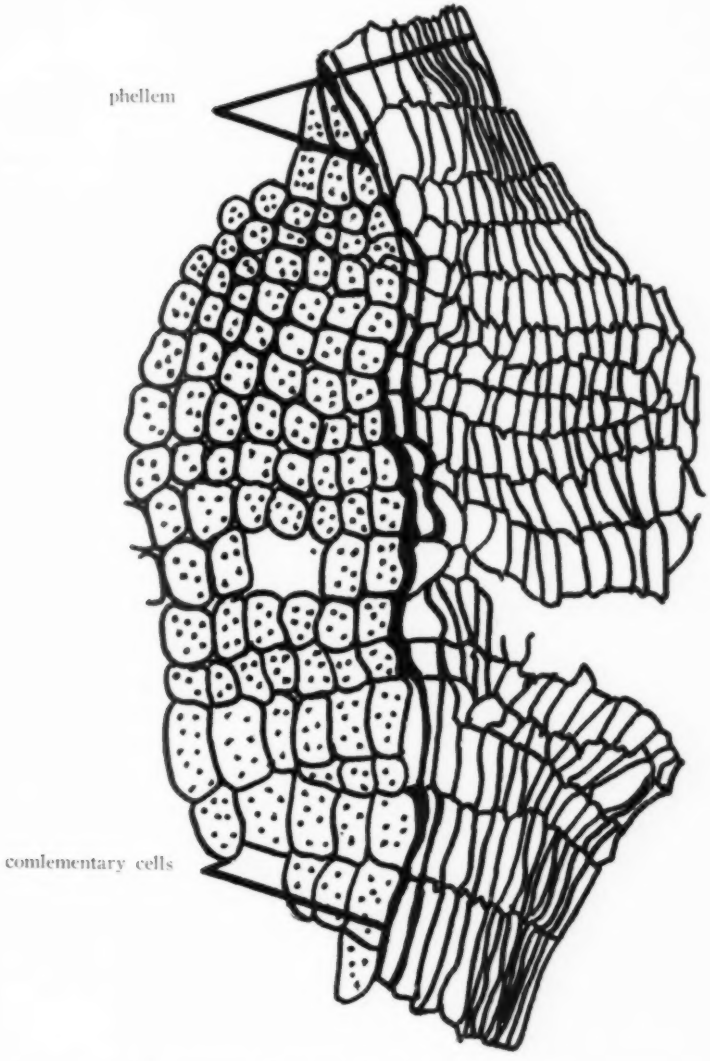

FIGURE 3.—Semidiagrammatic drawing of the lenticel structure characteristic of Pontiac tubers. X500.

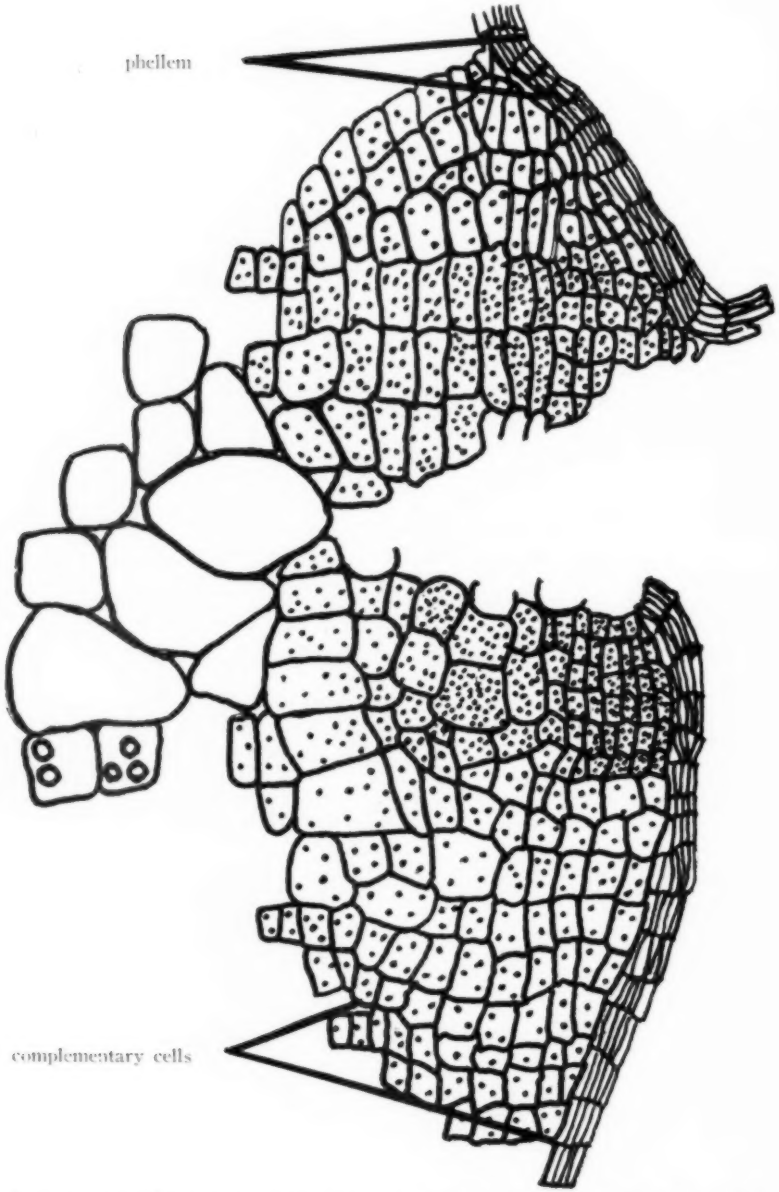

FIGURE 4.—Semidiagrammatic drawing of the lenticel structure characteristic of the Green Mountain, Katahdin and Ontario tubers. X100.

Ontario variety, with Katahdin and Green Mountain in between The susceptibility of these same varieties to black spot has consistently fallen into the same relative position for many years.

If varietal differences are caused by their ability to retain or lose moisture, there should be an association between shrinkage and black spot among varieties. Table 8 gives some of the shrinkage and black spot data from the latest three variety tests at the Long Island Vegetable Research Farm. The average black spot for the four varieties which had the most and the least shrinkage after five months storage at 50° F. are given. The low shrinkage varieties have significantly less black spot than the high shrinkage varieties.

These results are in agreement with what would be expected if firmness and turgor are the essential physical factors for triggering black spot. Large differences in shrinkage among varieties were reflected in black spot susceptibility. However, this did not hold true with small shrinkage differences.

General Discussion

The effect on black spot of cell turgidity, quality and quantity of ventilating air in storage, varietal variation in lenticel and skin structure, and specific gravity variation within a lot, indicate a possible physical phenomenon necessary for the chemical reaction which causes black spot. This physical factor is tuber firmness.

The evidence presented in this paper indicates an explanation for the association between specific gravity and black spot which has been recognized within a given variety but not among varieties. Varieties differ in firmness and black spot susceptibility because of inherent differences in lenticel and skin structure, not because of inherent varietal differences in specific gravity. Within a given variety, the black spot association and specific gravity relationship exists because the higher specific gravity tubers tend to be those that have less moisture caused by such factors as fertilization, age, skinning, bruising or heat injury at harvest.

The importance of tuber firmness in controlling black spot was indicated by the effect of moisture application in storage and air movement in the storage. As both of these factors were manipulated to cause decreased moisture loss from the tuber, the incidence of black spot was decreased. Black spot was created at will in the laboratory by withdrawing water from tubers. This same tuber material became non-susceptible again if the water was replaced.

Sawyer (11) and Cotter (5) found that irradiation increased susceptibility to black spot. Irradiation is known to have a dehydrating effect. A possible explanation for the effect of irradiation on black spot is its effect on tuber firmness.

Apparently black spot is triggered by both chemical and physical factors. Wiant (15) found that raising the storage temperature, temporarily, decreased the susceptibility of tubers to black spot. The length of time necessary for this conditioning was too short to have a physical effect on turgor. This temperature effect must be on a certain reaction that takes place after the physical requirement has been met.

Summary

1. Black spot was produced in the laboratory in a reversible reaction by manipulating cell turgor.
2. The amount of air used in cooling potatoes affected black spot.
3. The addition of moisture to the ventilating air used in cooling potatoes lowered the incidence of black spot.
4. Skin characteristics such as lenticel and periderm structure indicate an explanation for varietal susceptibility.
5. The evidence presented in this paper indicates that tuber firmness is a physical factor important to the chemical reaction which gives black spot.

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THE INFLUENCE OF PHOSPHORUS ON THE GROWTH AND PHYSIOLOGY OF THE POTATO PLANT[1]

G. V. C. HOUGHLAND[2]

The use of superphosphate as an ingredient of fertilizers for potatoes is a long-established custom probably originating more than 100 years ago, when Sir J. B. Lawes first treated rock phosphate with sulfuric acid. Today superphosphate still occupies an important place in the list of essential fertilizer materials, sometimes even being referred to as the backbone of the fertilizer industry. However, despite its use for a long time in potato fertilizers and its recognition as an essential plant food element, phosphorus has come to be regarded as less critical for potatoes than nitrogen or potash. This view may be due in part to the fact that potato plants showing distinct symptoms of phosphorus deficiency are seldom seen and moreover are less easily recognized than those showing symptoms of nitrogen or potash deficiencies.

Another fact that tends to obscure the importance of phosphorus in potato production is its relatively low absorption by the plant compared with that of nitrogen and potash. It has been estimated (5) that potato vines absorb less than 15 per cent of the phosphorus in the fertilizer applied to the soil. Compared with an estimated 80-per cent absorption for nitrogen and 50-per cent or more for potash, (5) this is obviously a low rate of recovery. On the other hand, this low rate of phosphorus recovery by potatoes means that more than 85 per cent of the fertilizer phosphorus applied each year remains in the soil to build up phosphorus reserves. These reserves are further augmented in that only about 7 per cent of the applied phosphorus is removed by the potato tubers (9) whereas all the phosphorus remaining in the vines is returned to the soil.

The chemical and physical factors influencing phosphorus availability in the soil have been subjected to extensive research and although the importance of these factors is fully recognized, their inclusion in this paper would require a separate discussion which will not be attempted here. In the present work the phosphorus accumulations in the soil are considered only in regard to the bearing they may have on fertilizer practice. The present work is concerned directly with the physiological requirements of potatoes for phosphorus and only indirectly with the factors which may influence its availability in the soil.

Because of the existence of accumulated phosphorus residues in potato soils, it would appear logical that a reduction of the phosphorus in the fertilizer would be called for in order to make use of these reserves. However, this assumption was tested by Nelson and Hawkins (8), who conducted extensive experiments with potatoes in North Carolina and Maine and found that despite the phosphorus residues in the soil, yield responses were obtained from increasing P_2O_5 increments in the fertilizer. They stated that "It is interesting that even on soils high in amounts of accumulated phosphorus there is a response from applied P_2O_5 in both Maine and North Carolina."

[1]Accepted for publication October 1, 1959.

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Purpose of Experiment

The present experiment was conducted in an attempt to evaluate two of the probable reasons for this response of potatoes to phosphorus and to study, at the same time, the physiological role of phosphorus in the metabolism of starch as related to tuber development. In a broad sense, the primary purpose for using fertilizer on potatoes, state simply, is to supply phosphorus and other plant food elements in available and relatively concentrated form when the plant roots are small, thus stimulating the growth of stems and leaves. These in turn function to produce more roots and then more vines in an expanding growth cycle which culminates in a crop of potatoes. It is conceivable, therefore, that the time at which phosphorus is made available in this growth cycle and the amount of phosphorus supplied, both may have appreciable effects on the yields obtained. Consequently, time of application and amount of phosphorus supplied were designated the primary variables in the experiment.

Materials and Methods

The experiment was conducted in the greenhouse. A solution culture procedure especially adapted for growing potatoes was employed (6). Unlike many other crop plants, potatoes require a medium suitable not only for root growth, but also for tuber development. Such a medium was provided by mixing thoroughly one part, by weight, of No. 2 Terralite and five parts of washed building sand. Each culture unit consisted of a 2-gallon vitrified earthenware container filled with 6 kilograms of the sand mixture and with the opening in the bottom covered with nylon screen. The equipment used in setting up the experiment is shown in Fig. 1. One single-eye seedpiece of the Cherokee variety was planted in each culture unit at a depth of 2½ inches. Nutrient solutions were applied in duplicate to the surface of the sand mixtures at the rate of one liter per unit, once a week. The nutrient solutions used were based on the formula given by Hoagland (6), but modified to allow for the changes in phosphorus content.

At the start of the experiment, one series of plants was treated with a no-phosphorus nutrient solution for 50 days and another series similarly treated for 70 days. The nutrient solutions, containing two different levels of phosphorus, applied after 50 and 70 days, are listed in the first column of Table 1. Plants receiving a nutrient solution containing 63 ppm of phosphorus from planting until harvest served as controls.

When the plants were harvested at the different stages of growth they were divided as follows: (1) top of plant consisting of 6 mature leaves, (2) bottom of plant, (3) tubers, and (4) roots. The plant material was immediately dried, weighed, and finely ground. Phosphorus content was then determined on ashed material by the Fiske and Subbarow (3) colorimetric method.

Results and Discussion

By comparing the values presented in the second and third columns of Table 1 the extent of the phosphorus concentration in the top or meristem regions of the plants can be seen. This concentration was pronounced during the early stages of growth when phosphorus was supplied in the

FIGURE 1.—Equipment used in setting up the experiment including sand-Terralite mixture, nylon screen, tube for gauging planting depth, and single-eye seedpiece.

TABLE 1.—*Effects of varied phosphorus nutrition of potato plants on P absorption and translocation and on tuber dry matter.*

Phosphorus Treatment	Phosphorus in Dry Matter				Dry Matter in Tubers per Plant	Age of Plant
	Top	Bottom	Tubers	Roots		
	Per cent	Per cent	Per cent	Per cent	Gr.	Days
No P for 50 days	0.284	0.198	0.125	0.148	2.4	50
+21 ppm P—30 days	.369	.274	.228	.163	9.0	80
+21 ppm P—58 days	.208	.160	.201	.136	25.1	108
+63 ppm P—30 days	.806	.529	.307	.291	7.4	80
+63 ppm P—58 days	.422	.325	.354	.225	51.1	108
No P for 70 days	.139	.116	.111	.96	6.4	70
+21 ppm P—20 days	.188	.144	.120	.116	8.6	90
+21 ppm P—45 days	.158	.137	.159	.132	17.4	115
+63 ppm P—20 days	.722	.336	.171	.224	8.3	90
+63 ppm P—45 days	.566	.399	.311	.310	22.5	115
63 ppm P for 112 days (Control)	.265	.202	.259	.440	77.0	112

nutrient solution and even persisted to some extent where phosphorus was withheld for the first 50 to 70 days. As growth proceeded, however, certain important changes took place in the phosphorus concentrations in different parts of the plants, depending on the amounts of phosphorus made available and the age of the plant.

First we shall consider the results in Table 1 for the plants grown for the first 50 days without phosphorus. The data show the percentages of phosphorus deficiency in these plants. At this stage of growth the plants showed definite symptoms of phosphorus deficiency (retarded meristem development and dark-green leaf color). Of particular importance was the fact that the number and length of the tuber stolons and the roots were also adversely affected, as shown in Fig. 2, since the Cherokee variety normally produces a heavy set of tubers, the development of this characteristic apparently depends upon an adequate supply of phosphorus. The phosphorus found in the plants fed with a no-phosphorus nutrient solution came from the seedpiece, the washed building sand, and a trace from the tap water. These amounts, however, are considered negligible as compared with the amounts of phosphorus supplied later.

It is of interest to examine what took place in the 50-day phosphorus-deficient plants after they had been supplied nutrient solutions containing 21 or 63 ppm phosphorus for 30 days. The data in Table 1 show that these plants absorbed phosphorus readily, the greatest absorption occuring where the higher level of phosphorus was supplied. Even though the percentages of plant phosphorus had increased appreciably, there was little difference in tuber dry matter produced at the two phosphorus levels after 30 days' treatment. Fig. 3 presents striking evidence of the degree of growth recovery obtained when the plants were 72 days old. The plant in the middle receiving 63 ppm phosphorus for 22 days showed the first signs of recovery within three days after phosphorus was supplied and thereafter recovery progressed rapidly.

As the phosphorus treatments were continued, further changes took place in the plants. After 58 days of phosphorus treatment, when the plants were 108 days old, pronounced reductions in the phosphorus concentrations of the vines were evident (Table 1). These were accompanied by marked increases in tuber dry matter. It is significant that although the reduction in phosphorus concentration in the vines was more marked in the plants receiving 63 ppm phosphorus, their tuber dry matter after 58 days of phosphorus treatment was twice that of the plants receiving 21 ppm. This result illustrates a condition known to occur in plant physiological studies in which plants may appear to be the same yet actually differ in their chemical composition and thus are quite different in their potential producing capacities.

When the plants with induced phosphorus deficiency lasting 70 days were supplied phosphorus in the nutrient solution their recovery, in general, was slower than that of plants without phosphorus for 50 days (Table 1). Although these plants absorbed more phosphorus from the 63 ppm solution during the 20-day recovery period, the dry matter produced during this early stage of growth, as in the previous series, was the same for each level of phosphorus supply. However, the corresponding increase obtained in tuber dry matter after phosphorus feeding commenced was not nearly so marked as in the 50-day deficient series. Apparently the 70-day no-

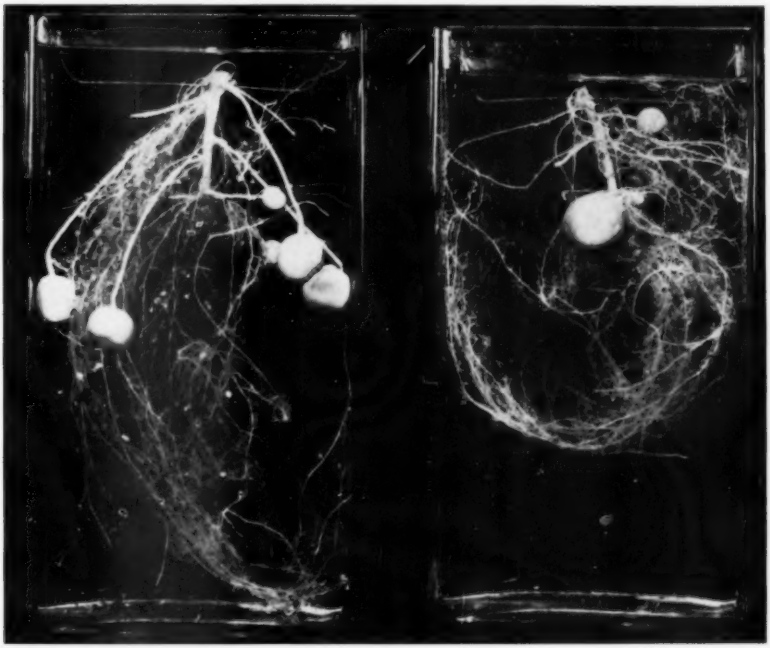

FIGURE 2—Comparison of the number and development of tuber stolons and tubers, and root growth in plants 50 days old. Left: 63 ppm phosphorus. Right: no phosphorus.

phosphorus period had exceeded the point of active recovery from phosphorus deficiency. Lyness (7), working with the corn plant, also obtaned prompt response to phosphorus feeding after 42 to 49 days of deficiency, but failed to get a response after withholding phosphorus for 63 to 70 days. When phosphorus was withheld too long, he explained, it was not available for the vital life processes, such as mitosis, reduction of nitrates, and respiration and so growth could not continue and deterioration of plant tissue followed.

The extent of growth recovery obtained after the 70-day period of induced phosphorus deficiency is illustrated in Fig. 4. The plant on the left receiving only 21 ppm phosphorus in the nutrient solution never did fully recover. The length of stolons and the number of tubers were also adversely affected after the 70-day no-phosphorus period, as illustrated in Fig. 5. Even when phosphorus was supplied the plants for 45 days after the initial 70-day phosphorus deficiency period, tuber development was less than one-third that produced by the controls (Table 1 and Fig. 6).

The relation between tuber development and the reductions in concentration of plant phosphorus shown in Table 1 is important. This relation is indicated by the marked increases in tuber dry matter that took place

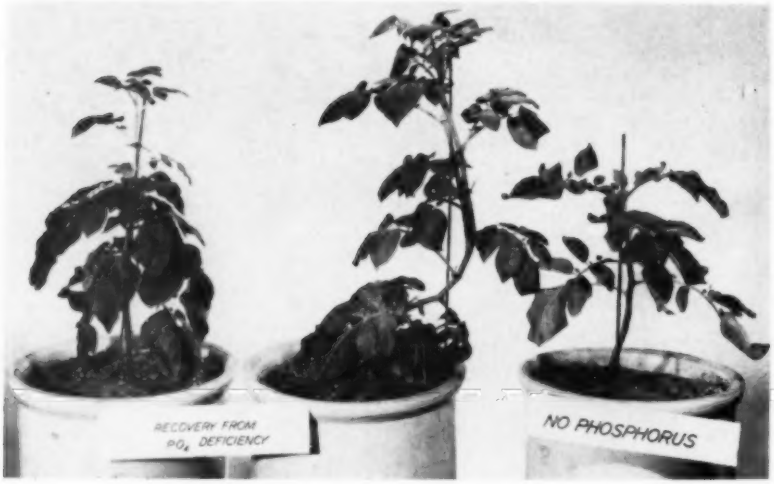

FIGURE 3.—Growth recovery obtained after feeding phosphorus for 22 days following a 50-day deficiency period. Left: 21 ppm phosphorus. Middle: 63 ppm phosphorus. Right: no phosphorus. All plants 72 days old.

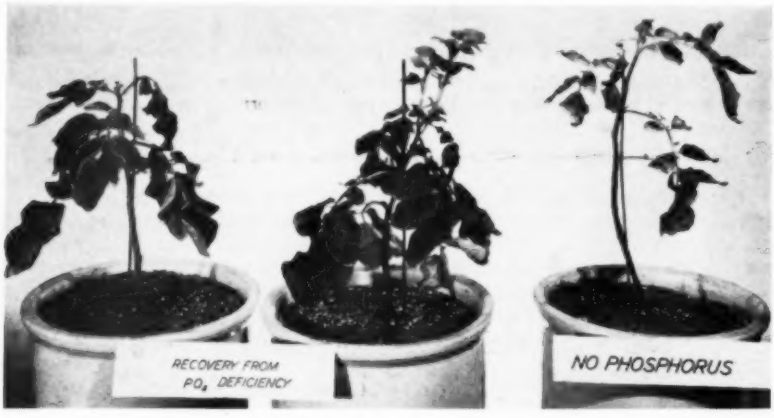

FIGURE 4.—Growth recovery obtained after feeding phosphorus for 16 days following a 70-day deficiency period. Left: 21 ppm phosphorus. Middle: 63 ppm phosphorus. Right: no phosphorus. All plants 86 days old.

when phosphorus was supplied the plants, especially after the 50-day period without phosphorus. Apparently a close connection exists between the translocation of plant phosphorus and the formation of carbohydrates and their storage in the tubers.

The actual phosphorus contents of the various plant parts are presented

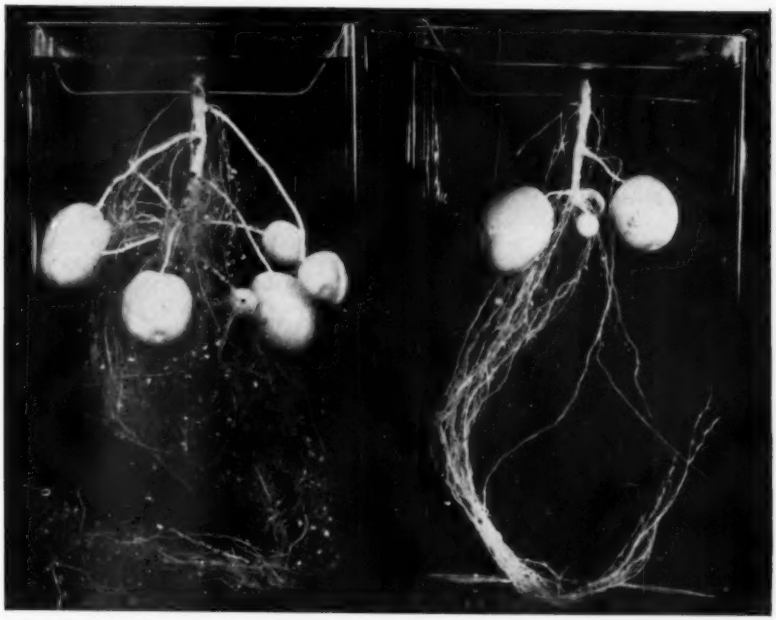

FIGURE 5.—Comparison of the number and development of tuber stolons and tubers, and root growth in plants 70 days old. Left: 63 ppm phosphorus. Right: no phosphorus.

in Table 2. In several instances these values show that the phosphorus content actually increased, whereas comparable data in Table 1 expressed as percentages of the dry matter indicate the reverse. In these cases the dry matter increased at a greater rate than the amount of phosphorus and thus caused apparent decreases in phosphorus content.

Percentages representing the proportion of the total plant phosphorus contained in the vines and tubers are also given in Table 2. These figures clearly indicate the extent of phosphorus movement from vines to tubers that normally takes place as the tubers develop. After 50 days without phosphorus the vines contained 57 per cent of the total phosphorus and the tubers 32 per cent. When the plants were supplied a nutrient solution containing 63 ppm phosphorus for 58 days, 15 per cent of the phosphorus was in the vines and 83 per cent in the tubers.

At the end of the 70-day no-phosphorus period (Table 2), the plants had 30 per cent of the total phosphorus in the vines and 63 per cent in the tubers, practically the reverse of that for the 50-day phosphorus-deficient plants. Such a ratio is associated with the premature onset of maturity in these plants. When fed 63 ppm phosphorus for 20 days, however, these plants had 41 per cent of their phosphorus in the vines and 51 per cent in the tubers. After a total of 45 days' phosphorus feeding the corresponding ratio was 31 to 65, indicating that although the plants were 115 days

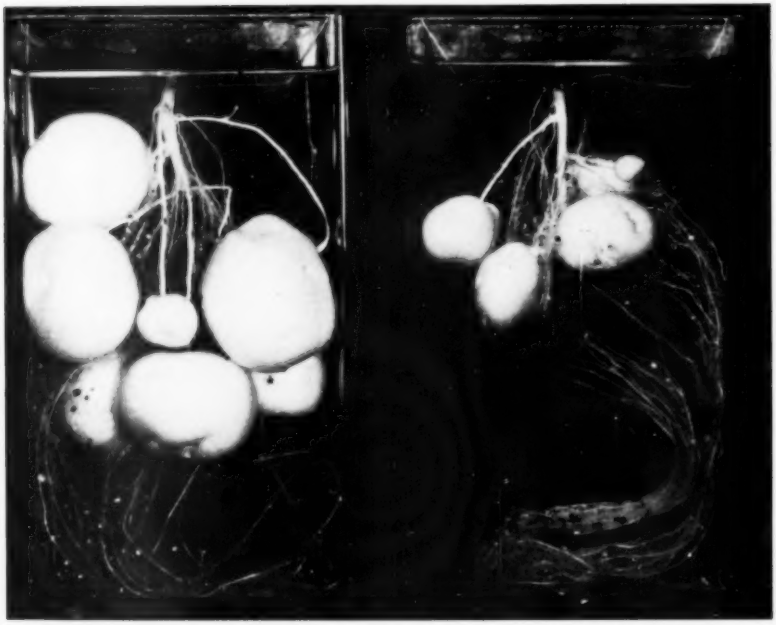

FIGURE 6.—Comparison of tuber development. Left: Control plants receiving 63 ppm phosphorus for 112 days. Right: Plants (115 days old) receiving 63 ppm phosphorus for 45 days following a 70-day deficiency period.

old, they were still physiologically less mature than the 112-day old control plants, which had 9 per cent of their phosphorus in the vines and 83 per cent in the tubers. These ratios clearly indicate the extent of phosphorus movement that normally takes place from vines to tubers during the growth cycle. They also point up the fundamental importance in potato production of an early and adequate supply of plant phosphorus needed in the metabolism of starch for tuber development. Lyness (7) also found that an adequate supply of phosphorus should be made available early in the life of the corn seedling and cited seven other workers whose conclusions verified this finding.

It is now appropriate to consider the results presented in Table 3 for a series of treatments, the reverse of those previously discussed. In this reverse series adequate phosphorus was supplied the plants in the nutrient solutions for the first 50 or 70 days. The sand mixture was thoroughly leached with water and thereafter all phosphorus was withheld for the periods indicated in the first column of Table 3. The data for the 50- and 70-day-old phosphorus-treated plants indicate the high percentages of phosphorus normally found in the vines, especially in the plant meristem region. However, when phosphorus was withheld after 50 days, the plant phosphorus decreased sharply during the next 30 days but the tuber dry matter continued to increase

TABLE 2.—*Effects of varied phosphorus nutrition on the phosphorus content of potato plants.*

Phosphorus Treatment	Phosphorus per Plant				Phosphorus in	
	Top	Bottom	Tubers	Roots	Vines	Tubers
	Mg.	Mg.	Mg.	Mg.	Per cent*	Per cent*
No P for 50 days	3.12	2.26	3.00	1.07	57	32
+21 ppm P—30 days	4.35	6.82	20.52	0.96	34	63
+21 ppm P—58 days	2.31	4.80	50.45	1.21	12	86
+63 ppm P—30 days	18.94	17.99	22.72	4.07	58	36
+63 ppm P—58 days	18.36	13.59	181.00	5.31	15	83
No P for 70 days	2.06	1.24	7.12	0.81	30	63
+21 ppm P—20 days	1.03	1.51	10.28	1.34	18	73
+21 ppm P—45 days	2.39	1.49	34.03	1.07	10	87
+63 ppm P—20 days	4.48	7.19	14.26	2.24	41	51
+63 ppm P—45 days	16.53	17.16	69.98	3.78	31	65
63 ppm P for 112 days (Control)	8.48	13.61	199.46	18.70	9	83

*Per cent of total for plant.

TABLE 3.—*Effects of withholding phosphorus nutrition on translocation of P in potato plants and on tuber dry matter.*

Phosphorus Treatment	Phosphorus in Dry Matter				Dry Matter in Tubers per Plant	Age of Plant
	Top	Bottom	Tubers	Roots		
	Per cent	Per cent	Per cent	Per cent	Gr.	Days
63 ppm P for 50 days	0.876	0.523	0.452	0.505	2.4	50
No P for 30 days	.307	.220	.313	.203	31.0	80
No P for 55 days	.128	.114	.218	.091	69.0	105
63 ppm P for 70 days	.828	.485	.428	.341	16.1	70
No P for 20 days	.343	.246	.325	.223	44.7	90
No P for 38 days	.155	.118	.266	.070	76.6	108
63 ppm P for 112 days (Control)	.265	.202	.259	.440	77.0	112

TABLE 4.—*Effects of withholding phosphorus nutrition on the phosphorus content of potato plants.*

Phosphorus Treatment	Phosphorus per Plant				Total P in—	
	Top	Bottom	Tubers	Roots	Vines	Tubers
	Mg.	Mg.	Mg.	Mg.	Per cent*	Per cent*
63 ppm P for 50 days	20.50	17.10	13.02	6.21	66	23
No P for 30 days	10.59	18.11	97.97	5.68	22	74
No P for 55 days	3.89	7.75	150.42	1.50	7	92
63 ppm P for 70 days	21.94	35.40	68.91	8.08	43	51
No P for 20 days	12.55	22.44	148.52	5.44	19	79
No P for 38 days	4.93	8.40	203.76	3.05	6	93
63 ppm P for 112 days (Control)	8.48	13.61	199.46	18.70	9	83

*Per cent of total for plant.

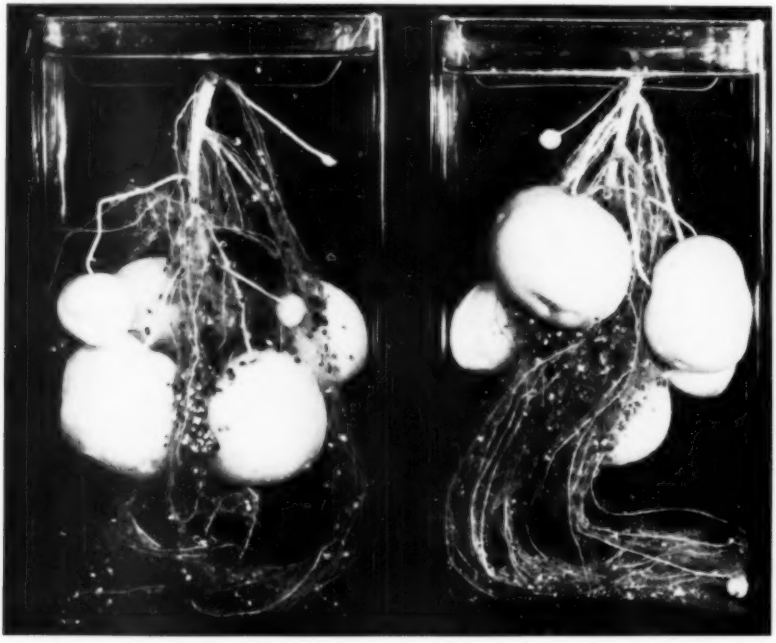

FIGURE 7.—Comparison of tuber development and number in plants. Right: plants receiving 63 ppm phosphorus for 50 days followed by no phosphorus for 55 days (total 105 days). Left: 63 ppm phosphorus for 70 days followed by no phosphorus for 38 days (total 108 days).

Similar decreases in the perecentages of plant phosphorus were also exhibited by the plants from which phosphorus had been withheld after 70 days of full nutrition. These plants, after receiving no-phosphorus nutrition for 38 days, produced practically the same tuber dry matter at 108 days as did the control plants at 112 days. Apparently after 70 days, and to a less extent after 50 days of full nutrition the plant had obtained sufficient phosphorus to fulfiill the requirements for normal tuber development. Gericke (4) obtained similar results with wheat plants. He was able to satisfy the full phosphorus requirements of the plants by feeding phosphorus only during the first 4 weeks of growth. When Arnon and Hoagland (1) transferred flowering tomato plants from +P solutions to —P solutions they found that fruit formed at the expense of the phosphorus absorbed earlier.

The extent of downward movement of phosphorus accompanying tuber development is indicated also by the data showing the amounts of phosphorus contained in the different plant parts in Table 4. The amounts of phosphorus in the vines and roots decreased markedly after phosphorus nutrition was withheld, but the amounts of phosphorus in the tubers continued to increase. When expressed as percentages of dry matter (Table 3), some of the significant increases in total tuber phosphorus were obscured.

The last two columns in Table 4 show the distribution of plant phosphorus between vines and tubers. At the end of the initial 50-day period of phosphorus feeding, 66 per cent of the phosphorus was in the vines and 23 per cent was in the tubers. However, at the end of the 70-day period 43 per cent was in the vines and 51 per cent in the tubers. After 112 days, only 9 per cent of the phosphorus was left in the vines and 83 per cent had reached the tubers. When phosphorus was withheld from the nutrient solution after the initial 50- or 70-day periods of phosphorus feeding, the translocation of plant phosphorus from vines to tubers was accelerated and the tuber development was practically unaffected, as illustrated in Fig. 7.

Summary

In any study on the importance of phosphorus in potato production it is essential to recognize the fundamental significance of the phosphate esters in plant growth, particularly their role in the conversion of carbohydrates and in the metabolism of starch. In a recent article on the influence of phosphoric acid on the metabolism of plants published by Behrens and translated by Sauchelli (2), the statement was made that "Carbohydrates can enter into the metabolism of plants only by way of the carbohydrate-phosphoric acid esters. If, as a result of phosphorus deficiency, the carbohydrates cannot be made use of, the plants stop building up secondary substances and may also lack energy for chemical synthesis and growth."

The results of the present investigation have amply confirmed the need for phosphorus in the growth of the potato plant and in tuber development. Moreover, this need has been shown to be highly critical during the early stage of growth when normal meristem development and rapid vine growth are essential for a good crop. Evidence that relatively large amounts of plant phosphorus were needed for subsequent starch phosphorylation is supplied by the finding that tubers from 50-day-old

plants contained only 23 per cent of the total plant phosphorus, whereas tubers from control plants, 112 days old, contained 83 per cent. Viewed from the standpoint of its importance in starch metabolism, the phosphorus contained in potato fertilizers has significance far beyond that heretofore fully recognized.

From the results obtained, which show clearly the fundamental need for phosphorus early in growth of the potato plant, it is understandable why potato yields can be expected to increase when a readily available form of phosphorus is applied to soils well supplied with residual phosphorus.

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FUNCTIONS OF THE PROTEIN AND OTHER NITROGENOUS FRACTIONS OF POTATOES IN CHIP COLOR DEVELOPMENT[1]

ORA SMITH AND R. H. TREADWAY[2]

It is generally accepted that the color of potato chips is a result of the "browning" or Maillard reaction which occurs largely between amino acids and reducing sugars. Ramsey *et al* (4) indicated that casein and glucose may react in a similar manner to that of amino acids and sugars. Mohammed *et al* (3) also reported that the browning reaction with proteins occurred in a system of bovine serum albumen-glucose solution.

The present studies were conducted with the following objectives: 1) to prepare potato protein fraction in sufficiently pure form for browning reaction experiments, 2) to determine the means by which the potato protein fraction participates in browning reactions during chip frying and the relative reactivity of the protein nitrogen and the non-protein nitrogen and 3) to determine the extent of the browning reaction of the potato protein fraction with glucose, fructose and sucrose using a model system to simulate conditions prevailing in chip frying.

METHODS AND RESULTS

Preparation of Potato Protein Fractions: At each date of sampling six treatments were involved, namely, three harvest dates, September 26, October 14 and November 9, and two storage temperatures, 40° and 50° F. The six treatments were replicated twice. Potatoes were sliced and frozen immediately in crushed dry ice. Samples were freeze dried and stored at 0°.F. until used.

A weighed portion of the dry potato powder was mixed with four times its weight of water plus 0.5 per cent sodium bisulfite and allowed to stand at 32° F. overnight with occasional shaking. The sample was then filtered through a Buchner funnel using filter aid and the amount of filtrate measured. It was assumed that soluble protein was equally distributed in the filtrate and in the water remaining in the filter pad. Therefore, instead of washing the filter pad or re-extracting in an attempt to get 100 per cent recovery (which was found to be impractical), in subsequent calculations a correction was made for the amount of water left in the funnel.

Sodium sulfate was added to the filtrate to precipitate proteins. It was found that Na_2SO_4, as used by Howe (1) in the old method of isolating plasma proteins, tended to give a precipitate that was easier to centrifuge than did ammonium sulfate. It was further found that, in the absence of a refrigerated centrifuge, it was better to do this step at room temperature to avoid changes in solubility of the precipitate as the solution increased in temperature.

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Work done in part under contract with the United States Department of Agriculture and authorized by the Research and Marketing Act of 1946, supervised by the Eastern Utilization Research and Development Division, Agricultural Research Service.

[2]Cornell University, Ithaca, N Y., and Eastern Utilization Research and Development Division, Agricultural Research Service, U.S.D.A., Philadelphia 18, Pa., respectively.

The sodium sulfate precipitate was suspended in water and dialyzed for three days at 32° F. During this time the suspension first cleared, and then a precipitate was formed. After three days, the contents of the dialysis was centrifuged. The supernatant portion was decanted and made up to volume. This was the water soluble protein and corresponds to Levitt's albumen fraction. The precipitate was washed three times with water and dissolved in 1 M NaCl. This was designated NaCl-soluble or water-insoluble protein and corresponds to Levitt's (2) globulin fraction.

The water soluble protein was colorless or slightly milky. The precipitated NaCl-soluble protein was white, appearing slightly turbid in salt solution, and tending to darken if allowed to stand several days at room temperature, indicating the possible presence of tyrosinase.

The pH of the solutions during extraction and dialysis, as well as the pH of the two protein fractions, was about 5.8. To determine whether there was protein in the water soluble fraction, a trichloroacetic acid precipitation was made. It was found that one-third of the nitrogen in this fraction was precipitable protein while the remainder was non-precipitable protein or peptides

The protein solutions were analyzed for nitrogen by the micro Kjeldahl method, and the results presented in Table 1.

Relative Reactivity in the Browning Reaction of Potato Protein Nitrogen and Non-protein Nitrogen Alone and with Glucose, Fructose and Sucrose.

The protein solutions were used within three days after dialysis was completed. Whatman No. 1 filter paper discs were dipped into the solutions and subsequently fried for two minutes at 380° F. The protein solutions were used alone and in combination with 0.05 M glycine and 0.05 M glucose, fructose and sucrose. The discs were washed with aliquots of carbon tetrachloride until a constant reading was obtained on the Hunter Color Difference Meter. Data of the January 16 sampling are presented in Tables 2 and 3. The data of the harvests of October 14 with potatoes stored at 40° F., November 9 with potatoes stored at 50° F. and October 14 with potatoes stored at 40° F. until April 23 followed by three weeks storage at 75° F. are presented in Table 4.

The original protein extraction of the first sampling on January 16 was intended to be a split, split plot analyzed by covariance, using color of discs from solutions without protein as the independent variable. Midway through the extractions it was apparent that protein was adding nothing, at least visually, to the color of the filter paper discs, therefore, only one replication was made. Consequently, time of harvest and storage temperature were confounded with extraction procedure, but since the difference was not significant statistically for soluble protein ($F = 2.15$ at 2 and 2 d.f. for date and $f = 1$ at 1 and 2 d.f. for temperature) this does not matter. Also since replications were dropped, the error term used to test date x temperature is deceptively small. However, the interaction is not significant ($F = 2.5$ at 2 and 83 d.f.) for soluble protein and would be still smaller if the error was correct.

The split plots, which are the different solutions, present a problem in analysis. Values were transformed to log $(1/Rd \times 10^2)$. There is a significant difference between discs dipped in solutions containing soluble protein and in those without soluble protein. It seems most likely, however, that

TABLE 1.—*Protein fractions of potatoes of three harvests and two storage temperatures.*

Harvest date	Storage temperature	Protein (6.25 x N) as per cent dry weight	
		H_2O soluble	NaCl soluble
Sept. 26	50°	5.21	3.52
Oct. 14	50°	..	..
Nov. 9	50°	4.77	..
Sept. 26	40°	5.16	3.50
Oct. 14	40°	4.33	3.70
Nov. 9	40°	5.24	..

TABLE 2.—*Color of filter paper discs (Rd)*fried after dipping in soluble protein fraction of potato tubers from three harvests and two storage temperatures, with and without glycine, glucose, fructose and sucrose (Jan. 16 sampling).*

Disc Number and Treatment	Stored at 50° F.			Stored at 40° F.		
	Date of Harvest			Date of Harvest		
	Sept. 26	Oct. 14	Nov. 9	Sept. 26	Oct. 14	Nov. 9
1. Water	61.7	61.3	60.8	62.3	61.9	60.8
2. Protein	62.0	60.4	61.4	62.1	60.6	61.8
3. Protein-glucose	59.5	59.7	59.2	60.0	59.2	58.8
4. Protein-fructose	60.5	55.6	59.8	58.7	57.6	58.8
5. Protein-sucrose	62.1	58.6	60.6	61.5	61.0	60.3
6. Protein-glycine	60.5	57.9	58.9	60.2	58.7	59.2
7. Protein-glucose-glycine	20.4	20.1	27.1	23.2	20.6	23.5
8. Protein-fructose-glycine	20.0	20.4	24.2	21.4	20.3	20.2
9. Protein-sucrose-glycine	50.4	34.5	43.4	41.0	34.7	35.9
10. Glucose	62.0	61.3	61.1	61.7	61.2	60.5
11. Fructose	62.5	61.0	61.8	61.8	61.3	60.2
12. Sucrose	63.4	61.1	61.6	62.1	60.9	61.6
13. Glycine	61.8	57.0	60.3	59.4	58.2	57.9
14. Glucose-glycine	21.7	20.2	22.9	23.2	22.0	20.3
15. Fructose-glycine	19.6	22.2	23.9	22.8	21.2	22.1
16. Sucrose-glycine	50.2	36.5	51.5	49.9	41.2	41.5

*White discs have Rd of 60 or above. The lower the Rd, the darker the disc.

the increase in color is due to the fact that the solutions remained in the cold room several days before the fryings were made. There are two points that bear this out, first, the fact that there is no difference between the various protein solutions although we know from the chemical analysis that the protein solutions differed in amounts of nitrogen and, second, the results from the second protein sampling.

Only the October 14 harvested tubers stored at 40° and the November 9 harvested tubers stored at 50° F. were extracted for protein the second time, on April 23. The protein solutions were fried on filter paper discs within 24 hours after dialysis. When paired samples were analyzed separately by the "t" test there was no significant difference (t value of 0.4 to 0.6 for 7 d.f.). Since protein contributed nothing to the color of the discs in this experiment, it seems doubtful that it had any effect in the others.

TABLE 3.—*Color of filter paper discs (Rd)* fried after dipping in insoluble protein fraction of potato tubers from three harvests and two storage temperatures, with and without glycine, glucose, fructose and sucrose. (Jan. 16 sampling).*

Disc Number and Treatment	Stored at 50° F.			Stored at 40° F.		
	Date of Harvest			Date of Harvest		
	Sept. 26	Oct. 14	Nov. 9	Sept. 26	Oct. 14	Nov. 9
1. Water	62.4	60.5	60.7	63.7	63.4	59.8
2. Protein	61.6	59.8	61.7	62.6	63.3	60.7
3. Protein-glucose	61.3	59.6	60.0	62.4	61.7	60.6
4. Protein-fructose	57.8	59.6	58.9	60.6	63.1	59.9
5. Protein-sucrose	60.8	59.6	60.5	62.4	63.4	60.5
6. Protein-glycine	57.3	57.2	57.2	58.4	58.4	58.5
7. Protein-glucose-glycine	20.9	28.6	24.7	24.6	22.3	26.0
8. Protein-fructose-glycine	28.6	23.1	24.3	23.6	23.1	26.7
9. Protein-sucrose-glycine	27.8	42.2	34.6	38.6	37.1	43.6
10. Glucose	61.9	59.7	61.3	61.4	62.6	60.3
11. Fructose	60.4	59.5	60.8	63.1	61.9	61.1
12. Sucrose	61.8	61.0	60.6	62.4	63.1	60.7
13. Glycine	57.0	56.3	57.7	58.8	57.9	58.0
14. Glucose-glycine	23.0	24.3	24.6	26.8	26.5	25.8
15. Fructose-glycine	24.0	29.5	23.5	18.5	20.8	25.9
16. Sucrose-glycine	41.8	39.1	32.9	38.0	36.3	41.6

*White discs have Rd of 60 or above. The lower the Rd, the darker the disc.

Insoluble and soluble protein values were analyzed statistically, "t" being about the same in both cases.

Tubers harvested October 14 and stored at 40° F. were reconditioned at 75° F. for three weeks at which time they made chips with an Rd reading of 24.8, compared to an Rd of 3.2 before reconditioning. Proteins were extracted in the usual manner and fried in combination with sugars and glycine on filter paper discs.

The water soluble protein sample was combined with 0.01 M sucrose and 0.23 M glycine instead of the usual 0.05 levels of each. Glucose and fructose concentrations remained at 0.05 M, however. The sodium chloride soluble protein was combined with sugars and glycine (0.05 M) separately, but not with both glycine and sugars at the same time.

For some reason, all the solutions, including the checks, fried considerably lighter in color than previously. Table 4 presents the data for color (Rd) of filter paper discs fried with the various combinations of sugars, glycine and protein fractions.

Using Student's "t" to compare paired samples with and without protein showed that neither soluble nor insoluble protein was significant. ($t = 0.5$ and 0.1 at 7 and 5 d.f.).

By visual observation, there appears to be no effect of the protein on browning in the model system. If discs from solutions 1 and 2, 6 and 13, and 7 and 14 (Tables 2 and 3) are compared, little difference can be detected. There certainly appears to be no difference between temperatures and harvest date treatments as a result of the protein fractions.

Rd readings of the Hunter Color Difference Meter show also that

TABLE 4.—*Color of filter paper discs (Rd)*fried after dipping in soluble protein and insoluble protein fractions of potato tubers from two harvests and two storage temperatures, with and without glycine, glucose, fructose and sucrose (April 23 sampling).*

Disc Number and Treatment	Harvested Oct. 14 Stored at 40° F.		Harvested Nov. 9 Stored at 50° F.		Harvested Oct. 14 Stored at 40° until April 23, 3 weeks at 75° F.	
	Soluble	Insoluble	Soluble	Insoluble	Soluble	Insoluble
1. Water	61.2	65.5	61.5	64.3	81.0	80.3
2. Protein	60.1	64.0	60.8	65.5	81.4	84.4
3. Protein-glucose	61.2	65.8	60.3	63.4	79.9	84.6
4. Protein-fructose	61.1	65.8	63.2	63.3	81.5	81.6
5. Protein-sucrose	61.2	65.0	59.3	63.8	81.2	83.1
6. Protein-glycine	58.4	62.3	59.3	61.9	75.4	80.6
7. Protein-glucose-glycine	31.0	31.7	30.3	28.5	32.8	..
8. Protein-fructose-glycine	23.5	29.9	27.5	28.3	33.1	..
9. Protein-sucrose-glycine	51.0	56.2	53.8	49.5	72.0	..
10. Glucose	61.2	66.2	60.1	61.8	80.7	84.0
11. Fructose	61.3	64.0	59.4	64.7	79.6	84.3
12. Sucrose	61.8	66.8	61.2	63.2	83.2	84.4
13. Glycine	59.6	63.0	59.1	62.8	78.2	82.3
14. Glucose-glycine	27.6	28.3	28.4	31.9	31.4	..
15. Fructose-glycine	27.6	33.5	22.6	37.4	33.1	..
16. Sucrose-glycine	56.0	55.3	54.9	54.1	78.2	..

*White discs have Rd of 60 or above. The lower the Rd, the darker the disc.

neither the soluble nor the insoluble protein fraction participates to any degree in the browning reaction. Numerous comparisons such as the following indicate this: 1 *vs* 2; 2 *vs* 10; 4 *vs* 11; 5 *vs* 12; 6 *vs* 13; 7 *vs* 14; 8 *vs* 15; 9 *vs* 16. This relationship holds regardless of date of harvest or storage temperature.

The only treatments that result in extensive browning reaction are those containing glycine with either glucose or fructose and to a lesser extent, with sucrose.

The earlier preliminary results in which there was some darkening can probably be explained as a result of growth of microorganisms. These solutions had been allowed to stand for quite some time before frying.

SUMMARY AND CONCLUSIONS

Both by visual observation and by Hunter Color Difference Meter measurements (Rd) there appears to be no effect of the protein, soluble or insoluble fractions, on browning in the model system. There also appears to be no difference in color of filter paper discs between storage temperature and harvest date treatments as a result of the protein fractions.

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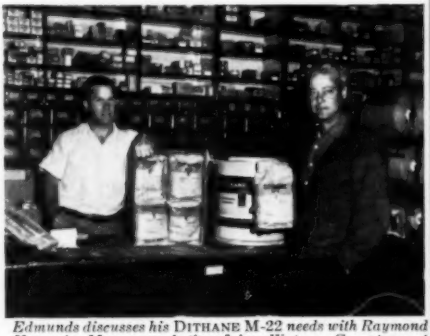
In attending to his many civic and business affairs, Edmunds finds that a neat and efficient office is a necessity.

Rohm & Haas field representative Bill Hughson joins Edmunds in a look at one of the water hazards on the new golf course.

Edmunds checks proper dosage of DITHANE M-22 *as McQuade fills sprayer. Both like the easy mixing of this 80% maneb fungicide.*



Edmunds discusses his DITHANE M-22 *needs with Raymond Howard, Manager of the John Watson Co. store at Fort Fairfield.*

Maine's E. Perrin Edmunds certified seed potato crop

DITHANE M-22... now 80% maneb
... from your partner in crop protection

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Judy, 5, and "Mike", 8, join their father on the front steps of the family home in Fort Fairfield. Pet Siamese cat, "Sim", relaxes while German Shepherd, "Ears", shows how he got his name.

Potato farmer-businessman E. Perrin Edmunds instructs farmhand Henry McQuade which field to spray next in his continuing potato blight control program.

prevents blight on his with DITHANE M-22

E. Perrin Edmunds, Fort Fairfield, Maine, recently ended his third term as president of the National Potato Council.

He is typical of today's progressive farmer—active community, state and national leader, successful businessman, and hard-working farm manager.

Currently, he is also a bank director, member of the State Legislature, president of C. A. Powers & Co., the John Watson Co., and Powers Starch Co., and building committee chairman for the local country club . . . now working on a new 18-hole golf course on which Edmunds will somehow find time to play.

Potatoes thrive on 700 of the rolling acres which make up the C. A. Powers & Co. potato operation. The crop is sold as certified seed. Culls and rejects are diverted to the company's potato starch plant located in Monticello, Maine.

Like most of his fellow potato growers, Edmunds puts his faith in DITHANE M-22 (maneb) fungicide for protection from early and late blight.

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NEWS AND REVIEWS

CALL FOR PAPERS

THE 44th ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA will be held at the American Baptist Assembly at Green Lake, Wisconsin, August 28-31.

Please send titles of papers to be presented at this annual meeting to Richard L. Sawyer, Long Island Vegetable Research Farm, Cornell University, Riverhead, New York, by May 15. Along with the title please include: (a) approximate time required to present your papers, (b) if an illustrated talk, the size of the slides to be used, and (c) the names and official addresses of the authors as you wish them to appear on the program. As has been our custom, we will again distribute mimeographed abstracts of these papers to members attending the annual meeting. These abstracts will be published in the American Potato Journal. Therefore, they should accompany the titles of the papers and should not exceed 250 words. Presentation of papers should not exceed 15 minutes, and the use of 2 x 2 slides is preferred.

We would like to receive good papers concerned with problems in potato breeding, diseases, production, quality, nutrition, storage, transportation, and marketing.

Your cooperation in sending the titles and abstracts as early as possible will aid in the mimeographing of these abstracts and the prompt preparation and printing of programs. Titles and abstracts received after our deadline of May 15 may not be accepted. Please bring this notice to the attention of your students and colleagues.

R. L. SAWYER, *Secretary*

GENERAL INFORMATION

ADVANCE DEPOSIT — To insure accommodations an advance deposit of $2.50 per person is required. This deposit is credited against the total bill of the guest.

CANCELLATIONS — If it is necessary to cancel a reservation, one-half of the advance deposit will be returned if the cancellation reaches our Registrar's office one week prior to reserved date.

CHECK-OUT TIME — Check-out time is 10:00 A.M. even though one may be remaining for the noon meal. This allows the housekeepers time to have rooms ready for in-coming guests by 3:00 P.M.

MEDICAL CENTER — The Assembly provides a Medical Center, with a nurse in attendance most of the year. All gusts are covered with travel and medical insurance from the point of departure and return.

GOLF — The Assembly owns and operates one of the finest 18-hole golf courses to be found anywhere in this country. It is open to the public at nominal charges, six days a week with no playing on Sunday.

SMOKING — For the comfort of guests, no smoking is allowed in any of the dining rooms and is discouraged in wooden buildings used as housing units.

Leading potato grower gets **INCREASED SPRAY EFFECTIVENESS** with **PLYAC*** Polyethylene Spreader-Sticker

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"The application of insecticides and fungicides is of utmost importance in the production of certified seed potatoes.

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INTOXICATING DRINKS — In our judgment, the use of alcoholic beverages in any form is incompatible with the aims and purposes of the Assembly. Thus guests who bring liquor on the grounds or who are under the influence of liquor will be asked to leave.

PETS — The Assembly has no facilities for caring for pets. Guests are requested not to ask for an exception to this policy.

TOURS — A field tour of research plots and potato variety trials will start at 1 P.M. on Saturday afternoon, August 27, at the Hancock Branch Experimental Station, Hancock, Wisconsin, and will continue in the central Wisconsin potato area on Sunday morning, August 28, before going to the Assembly near Green Lake for registration.

The Handcock Branch Station is located on highway 51 about 80 miles north of Madison. For those wishing transportation to Hancock from Madison on Saturday morning, August 27, cars will leave the Horticulture building on the University campus at 10 A.M. Contact R. H. Larson, Department of Plant Pathology, University of Wisconsin, Madison 6, Wisconsin.

TRAVEL INFORMATION TO AMERICAN BAPTIST ASSEMBLY, GREEN LAKE, WISCONSIN

BY AUTO — From *Milwaukee* it is a 90-mile drive on four-lane highway 41 to Fond du Lac, then highway 23 west to the Assembly gate. From *Minneapolis-St.Paul*, take route 10 to Stevens Point, then highway 73 to Princeton, highway 23 east to the Assembly. From *La Crosse*, take route 16 to Mauston, then east on highway 82 to highway 23, then east to the Assembly. From *Madison* take route 151 to Columbus, then highway 73 north to highway 23, east on highway 23 to the Assembly.

BY TRAIN — The Milwaukee Road runs four trains daily to Portage and the Chicago Northwestern Railroad runs three trains daily to Fond du Lac.

BY BUS — Greyhound buses run from: (1) Madison to Waupan to Green Lake. (2) Fond du Lac to Waupan to Green Lake. (3) Stevens Point to Green Lake.

BY AIR — North Central Airlines at Oskosh has many flights daily connecting with major air terminals: Chicago, Detroit, Milwaukee, Minneapolis and others.

MEETING GUESTS — By 24 hours advance notice to the Registrar, the transportation department will meet guests at Portage ($3.50), Fond du Lac ($2.50), Oshkosh ($2.50 or Green Lake Village ($.50) for each person. Transportation between 1:00 A.M. and 6:00 A.M. is discouraged, but if necessary the cost will be 50 per cent more than the above rates.

1960 RATES

THREE MEALS AND LODGING

These low American plan rates per day—per person—include lodging, medical and travel insurance, meal cost of $3.25 and use of "over 1000 acres" of assembly grounds, buildings and many recreational facilities. During the regular season, May 15 through September 30, there is a 25¢ per person per day service fee for non-Baptist groups.

ROOMS WITH CENTRAL BATH	3 or 4 Per Room	2 Per Room	1 Per Room
Abbey Area			
Oberlin Lodge	$5.25	$5.50	$7.00
Shepherd's Lodge	5.25	5.50	7.00
William Carey Hall	5.00	5.25	6.75
Cottages			
Moore		5.50	7.00
Parsons		5.25	6.75
Indian Village			
Bruce Kinney Dormitory	5.25		
Bruce Kinney Lodge, John Clarke Lodge	5.75	6.25	7.75
Brayton Case, Morehouse	5.75	6.25	7.75
ROOMS WITH SEMI-PRIVATE BATH			
Cottage			
Sunshine	6.00	6.50	8.00
Houses			
Barbour, Broadus, Jackson, Padelford		6.00	7.50
Burton, Kinbrook, Log Cabin, Laymon, Saunders	6.00	6.50	8.00
Dawson, Delmar, Montgomery	7.00	7.50	9.50
Robbins, Lawson, Oncken, Stambaugh	8.00	8.50	10.50
ROOMS WITH PRIVATE BATH			
Tower Court (Motel Style)		6.75	8.25
Roger Williams Inn	10.50	11.00	13.50

HOUSEKEEPING COTTAGES: A few housekeeping cottages are available (for 4, 6, 8 persons) at $7.00 to $12.00 per cottage per day, with private bath, blankets, linens and kitchen equipment (Meals may be taken at the Inn at cost up to $3.25 per day.)

CABINS: A few cabins are available (for 4, 6, 8 persons) at $6.00 to $10.00 per cabin per day with private or central baths. This does not include cost of meals which are $3.25 per day per person.

CHILDREN'S RATES: Ages 3 to 11 years, in rooms with parents, ½ the "2 Per Room" rate. Under 3 years $2.00 per day.

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Thimet is a systemic insecticide. It actually enters and protects the entire plant. Thimet is supplied to potato growers in granular form and is applied in bands along the row, at planting. As the crop starts to grow, the roots pick up the Thimet and send it up to the leaves, making them toxic to insects. Thimet provides even, steady control right through the season. Thimet eliminates the need to "time" insecticide applications.

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In many major potato areas, Thimet gives season-long control of aphids and leafhoppers; reduces flea beetle infestations. Because it stops leafhoppers, it helps control "purple top." In areas where late-season build-up of insects occurs, supplementary use of a conventional insecticide may be necessary.

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There are no residues in tubers at harvest, nor are chipping qualities affected when Thimet is used at recommended rates. Tests at Experiment Stations in Wisconsin and Ohio prove Thimet has no effect on flavor or chipping quality.

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On heavy or upland soils, apply 30 lbs. of Thimet 10% Granular Insecticide; on sandy or light soils apply 25 lbs. Do not use Thimet on muck soils. Be sure to follow directions and precautions printed on the package.

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Date of Departure ..... BB ☐ AM ☐ PM ☐ Eve ☐
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MEMO FROM: **CHEMICAL INSECTICIDE CORPORATION, Technical Staff**

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CHEM BAM + Manganese Sulphate		**Wettable Maneb**
Cost: $1.45 per gal. CHEM BAM .08 per lb. $MnSO_4$		Cost: $1.00 per lb. (approximate)
Use:		**Use:**
2 qts. CHEM BAM	$ .72½	1½ lbs. to 3 lbs.
1½ lbs. $MnSO_4$	.12	$1.50 to $3.00 per acre

FACTS:

1. 2 qts. of CHEM BAM requires 1½ lbs. $MnSO_4$ to complete the reaction to form Maneb.
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